Total Maximum Daily Load
For Siltation
Lake Keomah
Mahaska County, Iowa

August 8, 2002

Iowa Department of Natural Resources
Water Resources Section

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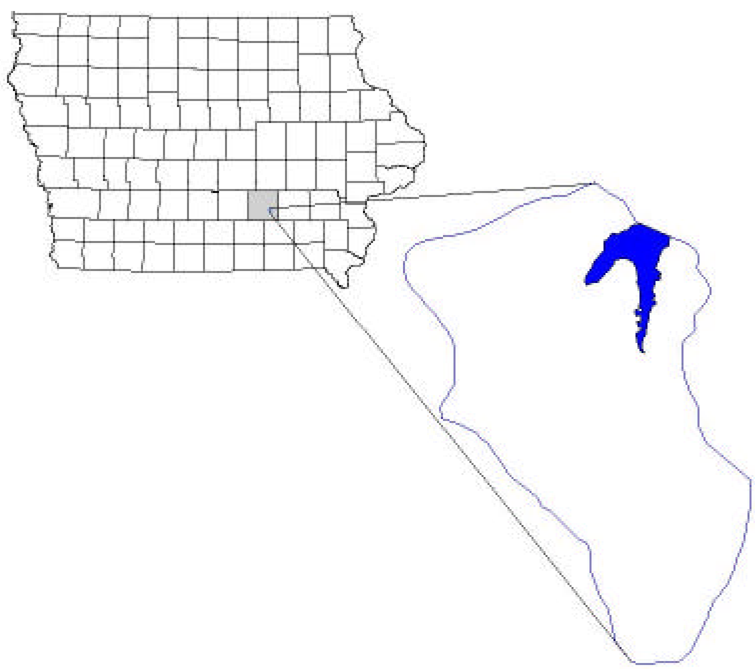
TMDL for Siltation
Lake Keomah
Mahaska County, Iowa

Waterbody Name:	Lake Keomah
IDNR Waterbody ID:	IA 03-SSK-00120-L
Hydrologic Unit Code:	070801051204
Location:	Sec. 24, T75N, R15W
Latitude:	41° 17 min N
Longitude:	92° 32 min W
Use Designation Class:	A (primary contact recreation) B(LW) (aquatic life) C (potable water source)
Watershed:	1,890 acres
Lake Area:	84 acres
Major River Basin:	Skunk River Basin
Receiving Water Body:	unnamed trib to the Skunk River
Pollutant:	Siltation
Pollutant Sources:	Agricultural NPS
Impaired Use	Aquatic Life
1998 303d Priority:	Low



1. Introduction

The Federal Clean Water Act (CWA) requires the Iowa Department of Natural Resources (IDNR) to develop a total maximum daily load (TMDL) for waters that have been identified on the state's CWA Section 303(d) list as impaired by a pollutant. Iowa's 1998 303(d) list, the current approved list, identifies Lake Keomah as threatened by siltation. The purpose of this sediment TMDL for Lake Keomah is to calculate the maximum amount of sediment that the lake can receive and still meet water quality standards, and then develop an allocation of that amount of sediment to the sources in the watershed.

Specifically this sediment TMDL for Lake Keomah will:

- Identify the adverse impact that sediment is having on the designated uses of the lake and how the excess load of sediment is threatening the water quality standards,
- Identify a target by which the waterbody can be assured to achieve and maintain its designated uses,
- Calculate an acceptable sediment load, including a margin of safety, and allocate the load to the sources, and
- Present a brief implementation plan to offer guidance to Department staff, DNR partners, and watershed stakeholders in an effort to achieve the goals of the TMDL and maintain the lake's intended uses.

The Iowa DNR believes that sufficient evidence and information is available to protect Lake Keomah from further degradation by sediment. The Department acknowledges, however, that additional information will likely be necessary. Therefore, in order to accomplish the goals of this TMDL, a phased approach will be used. This will allow feedback from future assessments to be incorporated into the plan.

Phase I of the sediment TMDL for Lake Keomah will be to maintain or reduce the sediment load that is threatening the aquatic life uses. Phase II will evaluate the effect that the sediment load target has on the intended results. In Phase II, monitoring of Lake Keomah will continue and the allocation of sediment will be reassessed. The phased approach allows the DNR to utilize a feedback loop to determine if the initial sediment load target has been effective in reaching the ultimate goal of this TMDL - to have the waterbody meet water quality standards and fully support the aquatic life designated use.

2. Description of Waterbody and Watershed

2.1 General Information

Lake Keomah is an 84 acre impoundment constructed in 1934. The lake is located 5 miles east of Oskaloosa, Iowa. Lake Keomah has a mean depth of 10 feet, a maximum depth of 18 feet, and a storage volume of 737 acre-feet. The lake is entirely within the 373 acre Lake Keomah State Park.

The lake and park provide facilities for boating, swimming, fishing, camping, picnicking and hiking. Park use is approximately 43,000 visits per year.

The Lake Keomah watershed has an area of approximately 1,890 acres and has a watershed to lake ratio of 26:1. The landuses and associated areas for the watershed are shown in Table 1.

Table 1. 2001 Landuse in Lake Keomah watershed.

Landuse	Area in Acres	Percent of Total Area
Cropland	832	44
Pasture and Hay	649	34
Timber	313	17
Other (urban, roads, etc.)	96	5
Total	1,890	100

In 2001, cropland comprised 44 percent of the watershed. Pasture and hay account for 34 percent of the watershed. There are 313 acres of timber in the watershed, many of which are in the state park. The remaining area includes urban areas, farmsteads, and roads.

Average rainfall in the area is 35 inches/year, with the greatest monthly amount occurring in June (DSC-DNR, 1991).

2.2 Current Watershed Conditions

A watershed project was established in the Lake Keomah watershed in 1993 to improve water quality in the lake. The watershed project focused on the implementation of Best Management Practices (BMP) that would reduce sediment and nutrient delivery to the lake. The project was completed in 1998. This project resulted in the construction of sediment basins, terraces, grassed waterways, and an animal waste system. In addition, other BMPs that were installed include residue management, seeded field borders, contour cropping, pasture management including stream corridor fencing and alternative watering systems.

The IDNR has recently constructed and renovated sediment basins on both of the main waterways to the lake. In 1994 a sediment basin on the east arm of the lake was rebuilt and enlarged. In addition, a sediment basin was constructed on the west arm of lake in 1998.

Monitoring and evaluation of Lake Keomah as part of this TMDL should provide indications if the improvements in the watershed have halted or reversed the downward trend in water quality due to sediment delivery to the lake.

Gross sheet and rill erosion for the watershed was calculated using the Revised Universal Soil Loss Equation (RUSLE) and sediment delivery to Lake Keomah was determined using the erosion and sediment delivery worksheet (USDA-NRCS, 1998). The average sediment delivery rate in the Lake Keomah watershed in 1998, at the end of the watershed project, was 1.8 tons/acre/yr. This rate is based on the total yield of 3,361 tons/yr of sediment delivered to Lake Keomah divided over the entire watershed. Current landuse and best management practices are similar to those at the end of the watershed project, therefore, it is expected that the current rate is comparable to the 1998 rate.

3. Applicable Water Quality Standards

The *Iowa Water Quality Standards* (Iowa, 2000) list the designated uses for Lake Keomah as Primary Contact Recreation (Class A), Lakes and Wetlands (Class B(LW)), and Drinking Water Supply (Class C). Lake Keomah also has general uses of secondary contact recreation, agricultural uses, domestic uses, and wildlife watering.

The State of Iowa does not have numeric water quality criteria for siltation that apply to Lake Keomah. Lake Keomah was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. Lake Keomah has been assessed as “fully supported-threatened” since 1994. This assessment was used for the 1998 303(d) list without being reevaluated. The DNR Fisheries Bureau indicated that sediment loading was threatening the Class B(LW) designated use. The Class B(LW) designated use states that the physical and chemical characteristics are suitable to maintain a balanced community normally associated with lake-like conditions (IAC 567-61.3(1)b(7)). IDNR field staff determined that excess sediment was threatening to alter the physical and chemical characteristics of the lake so that with additional sediment loading a balanced community normally associated with lake-like conditions could not be maintained. In the judgement of the field staff, beneficial uses of aquatic habitat, spawning and reproduction, and sport fishing would become impaired if the physical and chemical characteristics of the lake were further degraded.

A waterbody is fully supporting but threatened for a particular designated use when it fully supports that use now but may not in the future unless pollution prevention or control action is taken because of anticipated sources or adverse pollution trends. Monitoring and evaluative data indicated an apparent declining water quality trend in Lake Keomah in the 1998 305(b) report.

Activities in the watershed since 1993 have worked to reduce sediment delivery to Lake Keomah. The impacts of the water quality project and the IDNR-built structures on the downward trend in water quality have not been fully assessed, although watershed improvements should lead to improvements in the lake. This watershed project and additional work in the watershed have been completed after the assessment for the 303(d) list was made.

4. Water Quality Conditions

4.1 Water Quality Studies

Water quality surveys have been conducted on Lake Keomah by Iowa State University in 1979, 1990, and 2000-01 (Bachmann et. al, 1980, Bachmann et. al, 1994, Downing and Ramstack, 2001, Downing and Ramstack, 2002) and the University of Iowa Hygienic Laboratory in 1986 (Kennedy and Miller, 1987).

Samples were collected three times each summer for the lake studies conducted in 1979 and 1990 (Bachmann et. al, 1980, Bachmann et. al, 1994). This data is shown in Tables 2 and 4 in the Appendix.

In 1986, the University Hygienic Laboratory sampled Lake Keomah three times near the deepest part of the lake. On each sampling date, samples were collected from approximately the 0, 3, and 6 m depths. These results are shown in Table 3 (Appendix).

Lake Keomah was sampled again in 2000-01 as part of the Iowa Lakes Survey (Downing and Ramstack, 2001, Downing and Ramstack, 2002). This survey will sample the lake three times each summer for five years. The data collected in 2000-01 is shown in Tables 5 and 6 (Appendix).

The average total suspended solids values in 1986 was 18.3 mg/L. In 1990, the average value was 10.5 mg/l. Total suspended solids values continued to decrease in 2000 and 2001, with an average value in 2001 of 7.9 mg/L (see data tables in Appendix.)

4.2 Angling (provided by Mark Flammang, Fisheries Biologist)
The Lake Keomah fishery consists primarily of largemouth bass, bluegill, white and black crappies, and channel catfish. Additional species include green sunfish, redear sunfish, black bullheads, white bass, and northern pike. The latter two were likely illegally introduced by anglers and are present at very low densities.

A fish renovation project was undertaken by IDNR in 1981. At this time the lake was drained and the remaining impoundment was treated with rotenone. At this same time in-lake fish habitat was constructed including brush piles, islands and shoreline deepening. A selective kill of gizzard shad was performed in 1984 to rid the lake of this particular species. Gizzard shad are commonly associated with declines in bluegill quality and quantity and can eventually lead to problems with largemouth bass populations.

Among other species, grass carp were introduced to control a perceived problem with aquatic macrophytes in 1982. These fish were stocked periodically at a rate of 2 – 10 / acre. The last year of stocking was 1996. Since then, no more have been added. The lake is marked by a complete lack of aquatic macrophytes. It is currently part of IDNR's management plan to allow for increased aquatic macrophyte growth by removal and natural mortality of grass carp.

In 1998, gizzard shad were again discovered in the lake. Gizzard shad are a planktivore as well as a detritivore. Whatever the mechanism, their presence often leads to declines in other fish species numbers and quality. In the fall of 2001, population and biomass estimates were completed on important fish species in Keomah. The results are summarized by species below.

Largemouth Bass:
Largemouth bass are the primary predator species in Lake Keomah. Their density and size quality determine the quality of other panfish species like bluegill and crappie. From 1997 to 2000 we had a resident gizzard shad population present in Keomah. This population of prey species often causes some short-term gains in quality of largemouth bass. This was no exception. In the last 3 years Largemouth bass proportional stock density (PSD), a numeric way of quantifying size quality of fish species) has ranged from 51 to 82 since 1998. Relative stock density of preferred size fish (RSD-P, a way of quantifying large fish in the lake) has been between 5 and 46. The goals for management of this lake are that densities range between 40-70 for PSD and 10-40 for RSD-P. In this time, these goals have been met or exceeded. Density is believed to be high as suggested by high electrofishing catch rates in all years of recent sampling. A biomass estimate was performed in 2001, which yielded a biomass of 28 pounds per acre. This compares very favorably to other high quality largemouth bass fisheries in area lakes.

Bluegill:
Since 1996 we have seen a consistent decline in the catch rate of bluegill in Keomah. This suggests a declining density during that period. PSD has ranged from 29 to 47 in this period. RSD-P has remained at 0. Our goals for management of this population are 20-60 for PSD and 5-20 for RSD-P. This indicated size quality is poorer than we would prefer for this species in this system. The 2001 biomass estimate indicated a biomass of 43 lbs of bluegill per acre. This is approximately 10%-30% of what we would expect to find in a high quality fishery. It is likely the gizzard shad population has had a negative impact on this bluegill population and has actually replaced much of the bluegill biomass.

Crappie:
Crappie catch rates suggest Keomah is home to a relatively small crappie population. It seems to be driven by intermittent year classes that will produce large numbers of individuals one year, but will not produce a year class for up to several years after. This is not an uncommon situation for small southern Iowa impoundments. PSD has ranged from 4 to 98 and RSD-P has ranged from 0 to 5 in this time. Our goal for management is 40-70 for PSD and 10-40 RSD-P. We have not met our goal recently; however, with additional time it is likely these fish will reach the desired size.

Gizzard Shad:
Gizzard shad are not a desired species in Lake Keomah. They were first detected in 1998; however may have been present as far back as 1994. As outlined before, they often lead to declines in other species quality. This is particularly troublesome in the case of largemouth bass. Since the gizzard shad population became abundant it has replaced the other primary prey species, which is bluegill. However, the winter of 2000/2001 caused extremely high gizzard shad mortality and no individuals have been collected in 2001. As such, our high predator density has very little to eat at this time. Without a suitable food source we may see marked declines in largemouth bass quality and density in the near future. However, we may see improvements in bluegill density and quality in the absence of the gizzard shad.

5. Desired Target

The listing of Lake Keomah as impaired by siltation is based on narrative criteria. Lake Keomah was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. Lake Keomah has been assessed as “fully supported-threatened” since 1994. The DNR Fisheries Bureau indicates that sediment loading was threatening the Class B(LW) designated use. There are no numeric criteria for siltation applicable to Lake Keomah or its sources in Chapter 61 of the Iowa Water Quality Standards (Iowa, 2000). The targets for Lake Keomah include a sediment load as well as a measurement of the aquatic life. This is a phased TMDL and each phase incorporates a separate target. Phase I includes targets for sediment delivery to the lake. Monitoring the water quality and the fishery of the lake are included in both Phase I and Phase II.

5.1 Siltation

The Phase I sediment delivery target will address the amount of sediment delivered to the lake from the watershed. A direct measure of the sediment load is difficult to make given seasonal variability and actual measurement tools. Acceptable estimates using established soil loss equations can be made to predict the erosion rates in the watershed, and subsequent delivery to the lake.

Gross sheet and rill erosion for the watershed was calculated using the Revised Universal Soil Loss Equation (RUSLE) and sediment delivery to Lake Keomah was determined using the erosion and sediment delivery worksheet (USDA-NRCS, 1998). The average sediment delivery rate in the Lake Keomah watershed is 1.7 tons/acre/yr based on calculations in the Lake Keomah Watershed Project Final Report (Mahaska SWCD, 1998). This rate would yield 3,361 tons/yr of sediment.

Because the Class B(LW) designated use for Lake Keomah is fully-supported threatened, the siltation target is to maintain or reduce current sediment delivery rates to the lake. The sediment delivery target is set as the estimated current sediment delivery rate to Lake Keomah of 3,361 tons/year (based on the 1998 estimates and little change in the watershed.).

5.2 Aquatic Life

The Phase II aquatic life target for this TMDL will be achieved when the fishery of Lake Keomah is determined to be fully supporting the Class B aquatic life uses. This determination will be accomplished through an assessment conducted by the DNR Fisheries Bureau by the end of 2002. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This protocol is currently being used to develop benchmarks for the fishery of Iowa's lakes. The results from the Lake Keomah assessment will be compared with the benchmarks being developed. These assessments will include age, growth, size structure, body condition, relative abundance, and species.

6. Loading Capacity

The State of Iowa does not have numeric water quality criteria for siltation that apply to Lake Keomah. Lake Keomah was included on the list of Iowa impaired waters based on the best professional judgment of DNR field staff regarding the water quality. Excess sediment is threatening the Class B(LW) designated use.

The Class B(LW) designated use for Lake Keomah is fully supported/threatened, therefore the current sediment delivery rate to the lake should be maintained or reduced. The current sediment delivery rate to Lake Keomah is 3,361 tons/year. Therefore, the loading capacity for Lake Keomah is 3,361 tons/year of sediment. This sediment target should ensure that water quality is not reduced beyond the current level.

7. Pollutant Sources

Water quality in Lake Keomah is influenced only by nonpoint sources. There are no point source discharges in the watershed.

The watershed of Lake Keomah is comprised of 78% cropland and pasture. The majority of this land is in good management practices. This is due, in part to the conservation efforts of the previous twenty years. Very few areas exist in the watershed where good conservation practices are not in place.

Gross sheet and rill erosion for the watershed was calculated using the Revised Universal Soil Loss Equation (RUSLE) and sediment delivery to Lake Keomah was determined using the erosion and sediment delivery worksheet (USDA-NRCS, 1998). A watershed project for the Lake Keomah watershed was completed in 1998. As part of the project final report, gross erosion for the watershed was determined pre- and post-project. Pre-project gross erosion was estimated at 28,744 tons/year. Post-project gross erosion was estimated at 9,997 tons/year. This is a 65% reduction in gross erosion.

The extent of gully erosion in the watershed is uncertain. There is little to no active gully erosion on private land in the watershed. The state park area is comprised of a large timber area. A forestry management plan is being developed for this area by the IDNR Forestry Bureau. As part of this plan, the presence and severity of gullies will be determined. If gully erosion is found to be a problem in the state park lands, proper controls will be sought to reduce this source of sediment. Other sources of sediment are sheet and rill and streambed and shoreline erosion.

As calculated in the Lake Keomah Final Report, the post-project sediment delivery to Lake Keomah is 3,361 tons/year (Mahaska SWCD, 1998). This equates to an average post-project sediment delivery rate of 1.7 tons/acre/year.

Modeling of sediment delivery to Lake Keomah has been completed using a GIS based RUSLE model. While this model cannot estimate exact quantities of sediment transported through erosion, they can identify areas within the watershed that have higher rates of erosion and subsequent delivery potential. This model identifies the outer portion of the watershed as contributing the most sediment to the lake. In the Lake Keomah watershed the row crop areas, which are more susceptible to erosion, are located in the outer portion of the watershed. Corridors near the stream and the area near the lake in timber and pasture, appear to have a low potential erosion based on current landuse.

8. Pollutant Allocation

8.1 Point Sources

There are no point source discharges in the Lake Keomah watershed. Therefore, the Wasteload Allocation for sediment established under this TMDL is zero.

8.2 Non-Point Sources

Non-point sources of sediment to Lake Keomah are sheet and rill erosion, gullies, and streambank and shoreline erosion. The majority of the watershed is used for agriculture production, either row crop, hay, or pasture. The desired target is to maintain or reduce the current level of sediment delivery to the lake. The Load Allocation established under this TMDL is 3,361 tons of sediment delivered to the lake from the watershed each year.

8.3 Margin of Safety

The margin of safety for this TMDL is implicit. The dual targets for this TMDL assure that the aquatic life uses will be restored regardless of the accuracy of the sediment delivery target. Failure to achieve water quality standards will result in review and probable revision of the TMDL, allocations, and/or sediment management approaches. In addition, calculations were made using conservative estimates. RUSLE uses conservative calculations to calculate the gross erosion.

9. Seasonal Variation

This TMDL accounts for seasonal variation by recognizing that (1) sediment loading varies substantially by season and between years, and (2) sediment impacts are felt over multi-year timeframes. Sediment and nutrient loading and transport are predictable only over long timeframes. Moreover, in contrast to pollutants that cause short-term beneficial use impacts and are thus sensitive to seasonal variation and critical conditions, the sediment impacts in this watershed occur over much longer timeframes. For these reasons, the longer timeframe (tons per year) used in this TMDL is appropriate.

10. Monitoring

Monitoring will be completed at Lake Keomah as part of the Iowa Lakes Survey conducted by Iowa State University under contract with the IDNR. In-lake water monitoring will be completed three times per year for each of the field seasons 2000 – 2004. In addition, the DNR Fisheries Bureau will conduct an assessment of the fishery of Lake Keomah in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). At the completion of this assessment, the data will be evaluated to determine the listing status of Lake Keomah.

11. Implementation

The Iowa Department of Natural Resources recognizes that an implementation plan is not a required component of a Total Maximum Daily Load. However, the IDNR offers the following implementation strategy to DNR staff, partners, and watershed stakeholders as a guide to improving water quality at Lake Keomah.

Phase I of this TMDL is to maintain or reduce the amount of sediment delivered to Lake Keomah. Although a sediment reduction is not called for at this time, future work may be done in the watershed to continue to reduce sediment delivery to the lake. Modeling of sediment and nutrient delivery to Lake Keomah has been completed using a GIS based RUSLE model. While this model cannot estimate exact quantities of sediment transported through erosion, they can identify areas within the watershed that have higher rates of erosion. This model identifies the outer portion of the watershed as contributing the most sediment to the lake. This is due to the large amount of timber and pasture near the lake, and row crop in the areas farther from the lake. Corridors near the stream and next to the lake appear to have a low potential erosion based on current landuse.

As part of Phase I, the extent of gully erosion in the watershed will be evaluated. There is little to no active gully erosion on private land in the watershed. The state park area is comprised of a large timber area. A forestry management plan is being developed for this area by the IDNR Forestry Bureau. As part of this plan, the presence and severity of gullies will be determined. If gully erosion is found to be a problem in the state park lands, proper controls will be sought to reduce this source of sediment. Other sources of sediment are sheet and rill and streambed and shoreline erosion.

The Phase II aquatic life target for this TMDL will be achieved when the fishery of Lake Keomah is determined to be fully supporting the Class B aquatic life uses. The DNR Fisheries Bureau will assess Lake Keomah as Part of Phase II. This assessment will be in accordance with the Statewide Biological Sampling Plan protocol (Larscheid, 2001). This protocol is currently being used to develop benchmarks for the fishery of Iowa's lakes. The results from the Lake Keomah assessment will be compared with the benchmarks being developed. These assessments will include age, growth, size structure, body condition, relative abundance, and species.

Existing sediment structures in the watershed should be evaluated to determine their current trap efficiencies. Any sediment structures that are no longer efficient at retaining sediment should be improved so that they continue to effectively protect the lake. Aquatic macrophytes in the lake would provide needed habitat and food for the aquatic life, and utilize nutrients in the lake. Sediment removal from the lake may also be beneficial by restoring habitat in areas that have silted in.

12. Public Participation

Public meetings regarding the proposed TMDL for siltation for Lake Keomah were held in Des Moines and Oskaloosa on January 14 and January 22, 2002, respectively. A second follow-up meeting was held in Oskaloosa on June 11, 2002 to present the draft TMDL. Comments received were reviewed and given consideration and, where appropriate, incorporated into the TMDL.

13. References

Bachmann, R.W., T.A. Hoyman, L.K. Hatch, and B.P. Hutchins. 1994. A classification of Iowa's lakes for restoration. Department of Animal Ecology, Iowa State University, Ames, Iowa. 517 p.

Bachmann, R.W., M.R. Johnson, M.V. Moore, and T.A. Noonan. 1980. Clean lakes classification study of Iowa's lakes for restoration. Iowa Cooperative Fisheries Research Unit and Department of Animal Ecology, Iowa State University, Ames, Iowa. 715 p.

Downing, John A. and Joy M. Ramstack. 2001. Iowa Lakes Survey – Summer 2000 Data. Iowa State University, Department of Animal Ecology. January, 2001.

Downing, John A. and Joy M. Ramstack. 2002. Iowa Lakes Survey – Summer 2001 Data. Iowa State University, Department of Animal Ecology. January, 2002.

DSC-DNR. 1991. Watershed analyses Lake Keomah, Mahaska County. Division of Soil Conservation, Iowa Department of Agriculture and Land Stewardship, and Iowa Department of Natural Resources.

Iowa. 2000. *Iowa Administrative Code 567, Chapter 61, Iowa Water Quality Standards.*

Kennedy, J.O. and J.G. Miller. 1987. 1986 Iowa lakes study. Report 87-3. University Hygienic Laboratory, University of Iowa, Iowa City, Iowa. 363 p.

Larscheid, Joe. Statewide Biological Sampling Plan, July 2001.

USDA-NRCS. 1998. Field Office Technical Guide Notice No. IA-198. “Erosion and Sediment Delivery Procedure”, Section I, Erosion Protection.

USDA-NRCS. 1977. United States Department of Agriculture, Natural Resource Conservation Service. 1977. Soil Survey of Mahaska County, Iowa.

14. Appendix

Table 2. Data collected in 1979 by Iowa State University (Bachmann, et al, 1980).

Date Collected	7/6/1979			8/22/1979			9/5/1979			
Depth (meters)	0	2	4	0	2	4	0	1	2	4
Secchi (meters)	0.7			0.5			0.6			
Suspended Solids (mg/L)										
Dissolved Oxygen (mg/L)	11.9	9.5	7.6	13.9	3.1	0.0	10.5	11.0	7.9	0.2
Ammonia Nitrogen (mg/L)							0.1			
Nitrate-Nitrite Nitrogen (mg/L)							0.07			
Total Phosphorus (mg/L) PO4	.178	.192	.210	.370	.283	.567	.271	.295	.277	.283
Chlorophyll a (ug/L) Corrected	59.9	23.2	56.1	139.2	29.9	8.2	84.6	90.6	58.8	6.7

Table 3. Data collected in 1986 by the University of Iowa Hygienic Laboratory (Kennedy and Miller, 1987).

Date Collected	6/16/86			7/23/86			9/8/86	
Depth (meters)	0	3	5	0	3	5	0	6
Secchi (meters)	1.0			0.4			0.4	
Suspended Solids (mg/L)	11	10	24	30	54	58	14	21
Dissolved Oxygen (mg/L)	10.6	1.0	0.0	12.2	0.1	0.0	5.0	0.3
Ammonia Nitrogen (mg/L)	0.07	0.36	1.5	0.07	0.98	7.3	0.26	14
Nitrate-Nitrite Nitrogen (mg/L)	1.5	1.5	0.6	<0.1	<0.1	<0.1	<0.1	<0.1
Total Phosphorus (mg/L)	0.18	0.07	0.24	0.18	0.20	1.3	0.35	2.4
Chlorophyll a (ug/L) Corrected	21	16	13	167	24	20	82	85

Table 4. Data collected in 1990 by Iowa State University (Bachmann, et al, 1994).

Date Collected	5/19/90			6/24/90			7/22/90		
Sample Number	1	2	3	1	2	3	1	2	3
Secchi (m)	1.0			1.1			1		
Suspended Solids (mg/L)	14.8	14.7	13.1	8.5	9.2	8.6	8.1	8.6	9.4
Total Nitrogen (mg/L)	2.5	2.5	2.5	3.4	3.4	3.8	1.6	1.7	1.5
Total Phosphorus (mg/L)	.108	.089	.099	.105	.118	.122	.074	.056	.069
Chlorophyll a (ug/L) Corrected	18.8	10.5	18.8	7.9	13	18.5	33.7	40	38.1

Each sample was a composite water sample from all depths of the lake.

Table 5. Data collected in 2000 by Iowa State University (Downing and Ramstack, 2001)

Parameter	**6/27/2000**	**7/25/2000**	**8/17/2000**
Secchi Depth (m)	0.6	0.7	0.8
Chlorophyll (ug/L)	30	3	5
NH_3+NH_4^+ -N (ug/L)	1020	325	1314
NH_3 –N (un-ionized) (ug/L)	4	49	52
NO_3+NO_2-N (mg/L)	0.88	0.07	0.07
Total Nitrogen (mg/L as N)	1.96	1.32	1.78
Total Phosphorus (ug/l as P)	258	213	320
Silica (mg/L as SiO_2)	27	21	25
pH	6.9	8.5	7.8
Alkalinity (mg/L)	229	114	123
Total Suspended Solids (mg/L)	19.2	12.2	3.0
Inorganic Suspended Solids (mg/L)	13.3	5.0	0.7
Volatile Suspended Solids (mg/L)	5.9	7.2	2.3

Table 6. Data collected in 2001 by Iowa State University (Downing and Ramstack, 2002)

Parameter	**5/29/2001**	**6/26/2001**	**7/30/2001**
Secchi Depth (m)	2.0	1.5	1.3
Chlorophyll (ug/L)	5	16	23
NH_3+NH_4^+ -N (ug/L)	442	533	483
NH_3 –N (un-ionized) (ug/L)	15	71	227
NO_3+NO_2-N (mg/L)	0.94	1.41	0.35
Total Nitrogen (mg/L as N)	1.62	3.70	1.12
Total Phosphorus (ug/l as P)	48	51	128
Silica (mg/L as SiO_2)	9	9	11
pH	7.9	8.4	9.1
Alkalinity (mg/L)	121	111	86
Total Suspended Solids (mg/L)	4.9	7.8	10.9
Inorganic Suspended Solids (mg/L)	1.3	2.4	4.7
Volatile Suspended Solids (mg/L)	3.6	5.4	6.2

Lake Keomah and Watershed